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Unconscious influence over executive control: Absence of conflict detection and adaptation

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ABSTRACT

Executive control and its modulation of attentional mechanisms allow us to detect and adapt to conflicting information. According to recent studies, executive control functions may be modulated by unconsciously perceived information, although the available evidence is not consistent. In this study, we used a Flanker Task and employed Chromatic Flicker Fusion, a suppression technique that has been proposed as more adequate to elicit executive control functions, to assess conflict and conflict adaptation effects. Our results showed that, when suppressed, flankers did not evoke conflict related effects on performance. However, in trials where most flankers were incongruent, longer response times in congruent trials were observed, consistent with orienting responses. Our results help to support earlier theories regarding the inherent limitations of unconsciously perceived information, though future studies should further investigate why and under which conditions is the executive control system modulated by unconscious information.

1. Introduction

1.1. Executive control of attention

We are constantly exposed to an endless plethora of incoming information that overwhelms our senses. Importantly, the number and diversity of stimuli competing for a prioritized processing is exponential in modern times. It is, therefore, crucial that our cognitive system functions to properly deal with this abundant external stimulation by constantly managing the diverse and simultaneous sources of distraction. Failures in this function (i.e., not properly ignoring distractor stimuli or failing to override habitual responses), which are linked with certain pathologies (e.g., in schizophrenia; Cho, Konecky, & Carter, 2006), can pose critical hazards in our daily life (e.g., not attending to a sudden road danger due to a ringing telephone; Logan & Gordon, 2001; Mansouri, Tanaka, & Buckley, 2009).

The attention system, with its separable, yet interconnected brain networks –alerting, orienting and executive control – modulates the priority and controls the flow of information that is processed and attended (Fan et al., 2009; Mackie, Van Dam, & Fan, 2013; Posner & Fan, 2008). While the *alerting* network is associated with an increase in vigilance regarding possible impending stimuli, the

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orienting network is activated in response to stimuli that signal high behavioral significance and may then require urgent action. Finally, and most relevant to the present study, the *executive control* network functions to detect and resolve conflict between different sources of stimulation (Fan, Mccandliss, Fossella, Flombaum, & Posner, 2005; Mackie et al., 2013). According to recent theories (Fan, 2014; Wu et al., 2018), the general purpose of this network is to cope (reduce) information uncertainty, where conflict is viewed as a special case of increased uncertainty. Consequently, the executive control network plays a vital role in orchestrating the attention system, by either inhibiting or facilitating the prioritization of some stimuli over others (Corbetta & Shulman, 2002). Therefore, constant adjustments in perceptual selection, response biasing and the maintenance of contextual or goal-directed information reflect important functions of the executive control system, which are particularly critical in the face of difficult, novel or complex tasks (i.e., when a high degree of cognitive management is demanded) (Botvinick, Braver, Barch, Carter, & Cohen, 2001). These functions are mainly coordinated by pre-frontal areas, particularly the lateral pre-frontal cortex (lPFC) and the posterior medial frontal cortex (pMFC), operating in concert to coordinate the attentional system and implement more efficient responses to conflicting information (Koechlin, 2003; Miller, 2000; Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004).

Despite the enormous amount of information to which we are constantly exposed, the processing capacity of our attentional system is limited (Kahneman, 1973) and bound to be affected by the analysis of multiple information presented simultaneously. The direct consequence is cognitive conflict, which occurs when a specific feature of a stimulus is incompatible or incongruent with that of a second stimulus attribute, thus generating conflict or interference (Duncan, 1980; Zysset, Müller, Lohmann, & von Cramon, 2001). The anterior cingulate cortex (ACC), in conjunction with the adjacent pMFC, plays an important role as a monitoring system for conflict (Carter & van Veen, 2007; Cohen, Botvinick, & Carter, 2000). The ACC appears to detect and initiate neural responses following errors and decreased performance, as shown by the error-related negativity (ERN) – an event related potential in the ACC that is sensible to deviations from optimal performance (Braver, 2012). This, in turn, will be conveyed to other areas of the prefrontal cortex (e.g., lPFC) that will subsequently implement counter-conflict measures, leading to what is known as *conflict adaptation* (Carter & van Veen, 2007; Yeung, Botvinick, & Cohen, 2004). The effect of conflict adaptation is, then, the product of coordinated actions of the executive control system that result in a tendency to emphasize goal-directed stimuli (i.e., relevant to the task at hand) and to devalue distractors or conflicting stimuli (Botvinick et al., 2001; Egner & Hirsch, 2005; Ullsperger, Bylsma, & Botvinick, 2005). Importantly, the expectations regarding the utility of the information will determine its importance and prioritization in processing and, consequently, its behavioral impact. This expectation is learned throughout previously conflicting experiences (Gratton, Coles, & Donchin, 1992; Wang, Zhao, Xue, & Chen, 2016).

In laboratory settings, conflict can be evoked by the use of different tasks, such as the Stroop task (Stroop, 1935), priming paradigms (Meyer & Schvaneveldt, 1971; Tulving & Schacter, 1990), dual-tasks (Pashler, 1994) and the Eriksen flanker task (Eriksen & Eriksen, 1974). In these tasks, whenever the target is surrounded or preceded by congruent distractor stimuli (i.e., stimuli corresponding, or matching the target, therefore being associated with the same response), participants tend to be faster (i.e., exhibit shorter response times) and more accurate in identifying the target. A reverse effect is observed when the distractors are incongruent or incompatible with the target (i.e., stimuli that differ from the target, pointing to a different response) (Boy, Husain, & Sumner, 2010; Hasegawa & Takahashi, 2014; Larson, Kaufman, & Perlstein, 2009). The overall conflict caused by the distractors is assessed by comparing the differences between congruent and incongruent trials. Regarding adaptation effects, these can be viewed in terms of immediate adaptation (trial-by-trial), where the previous trial's congruency modulates the next one, or long-term adaptation (block-wise), where the previous group of trial's congruency modulates the current trial (Ansorge, Kunde, & Kiefer, 2014; Gratton et al., 1992; Kuratomi & Yoshizaki, 2013; Logan & Zbrodoff, 1979). Such adaptation effects (specifically long-term, which are more relevant to the current study) are formally analyzed by comparing compatibility indexes. These indexes are calculated by subtracting the mean performance measure (i.e., response times, accuracies or error rates) of incongruent trials, with the corresponding measure for congruent trials, in a given block of trials. This final value represents the degree of attendance given to distractors in that respective block (Hasegawa & Takahashi, 2014; Nieuwenhuis et al., 2006).

Although previous results are consistent in showing how our information management abilities, provided by executive control mechanisms, help us to detect and adapt to information that proves to be either disruptive or helpful to our current goals, such findings are mainly based on information that we consciously experience and perceive. Yet, the question of whether these mechanisms solely rely in conscious processing has only recently been put to test, as alluded in the following section.

1.2. The role of awareness in executive control processing

Until recently, goal-directed (or top-down) processing, such as that involved in executive control, was assumed to be limited to conscious processing, with unconscious processing (i.e., without awareness) being mostly associated with low-level operations (i.e., stimulus-driven or automatic), having a limited capability in undertaking high-level processes (i.e., complex computations) (Dehaene & Naccache, 2001; Kiefer & Martens, 2010; Posner, Snyder, & Solso, 2004). Attention is a paradigmatic example of a cognitive process that is highly intertwined with conscious processing (Posner, 1994). Indeed, the absence of attention is associated with the absence of awareness (i.e., conscious perception), as reflected by several attentional phenomena, such as inattentional blindness (Mack & Rock, 1998), change blindness (Simons & Levin, 1997) and attentional blink (Raymond, Shapiro, & Arnell, 1992).

Recent research has challenged the assumption that unconscious processing is restricted to automatic and less complex processing (Ansorge et al., 2014; Custers & Aarts, 2010; Silverstein, Snodgrass, Shevrin, & Kushwaha, 2015). Several studies seem to support, instead, a less restricted role of unconscious processing, from as basic as the conceptual integration of an object with its background (e.g., Mudrik, Breska, Lamy, & Deouell, 2011), to the selection and use of a strategy without intention or conscious awareness regarding the meaning of the cues (i.e., distractors) provided in the tasks (e.g., Ghinescu, Schachtman, Stadler, Fabiani, & Gratton,